DOE's Vehicle Technologies Office

MATERIALS TECHNOLOGY





U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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Materials Technology Program - Overview

Automakers are seeking to improve fuel economy while maintaining or improving vehicle performance and safety

Using lightweight components and high-efficiency engines in one quarter of the U.S. fleet could save more than 5 billion gallons of fuel annually by 2030

- For structural components, the market is shifting from traditional steel to lighter weight materials such as advanced high-strength steels, aluminum alloys, magnesium alloys, and carbon fiber composites.
- Lighter structures allow for downsizing engines and increasing power density which requires materials with low density, high strength, and high stiffness at elevated temperatures.

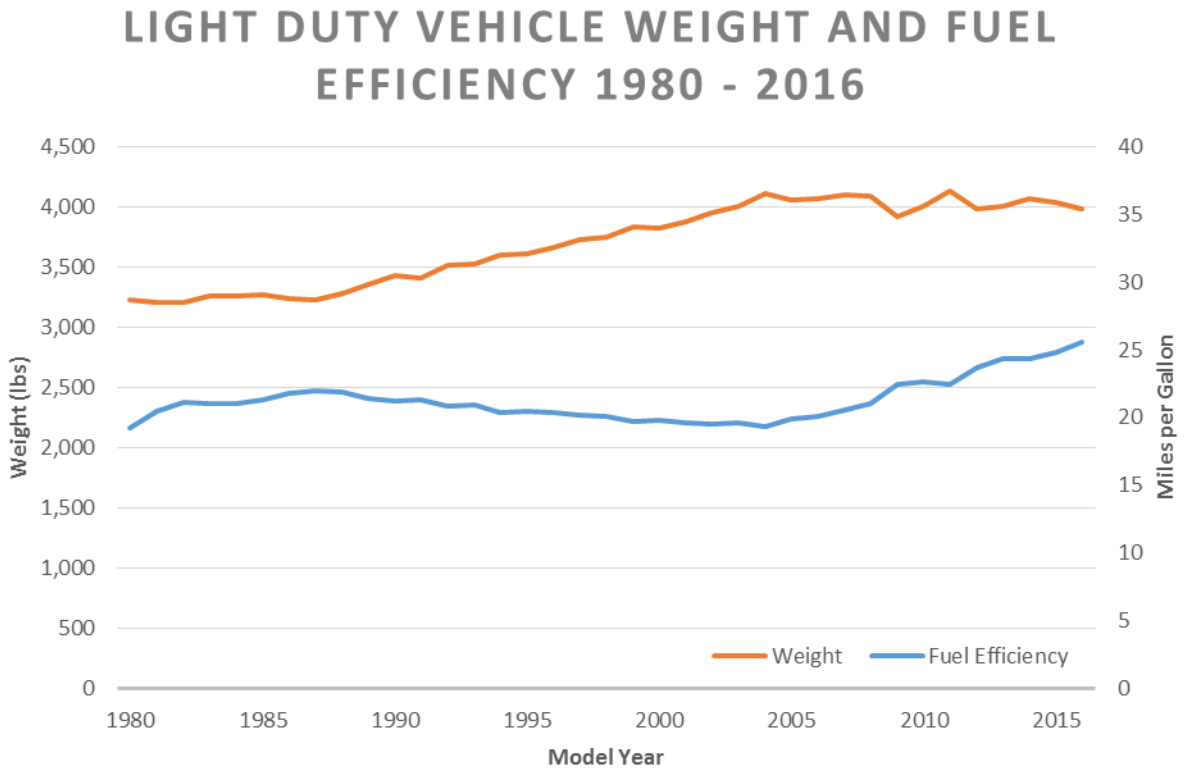
2017 Ford F-150

2018 Cadillac CT-6

2017 Chrysler Pacifica

2017 BMW i-3

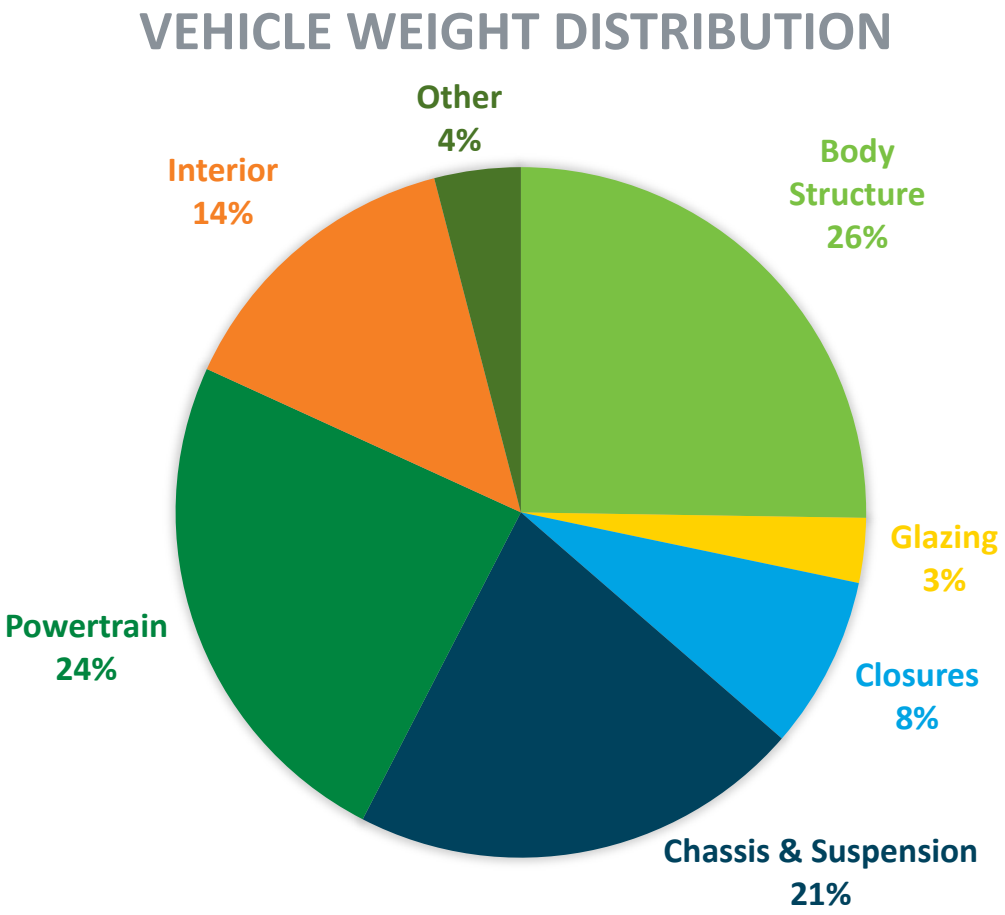
Materials Technology Program - Overview



- Reducing the weight of an internal combustion engine (ICE) vehicle by 10% can improve fuel economy by between 6% and 8%.
- A 13% improvement in freight efficiency can be achieved from a 6% reduction in vehicle weight when the reduced structural weight is replaced by cargo.

Materials Technology Program – Focus Areas

The Materials Technology Program focuses on enabling materials solutions in two areas: the glider and the powertrain materials.



- Goal: Enable a 25 percent weight reduction for light-duty vehicles including body, chassis, and interior as compared to a 2012 baseline at no more than a $5/lb-saved increase in cost;

- Goal: Validate a 25 percent improvement in high temperature (300 ^{o}C) component strength relative to components made with 2010 baseline cast aluminum (AL) alloys (A319 or A356) for improved efficiency of light-duty engines.

Material Technology - Significant Opportunities & Challenges

Increasing Severity of Challenge

Increasing Impact on Reducing Vehicle Mass

Material	Critical Challenges				
Carbon-Fiber Composites	Low-Cost Fibers	High-Volume Mfg.	Predictive Modeling	Recycling	Joining/ NDE & Life monitoring
Aluminum	Feedstock Cost	Manufacturing	Improved Alloys	Recycling	
Magnesium	Feedstock Cost	Corrosion Protection	Improved Alloys	Manufacturing	Recycling
Advanced High-Strength Steels	Manufactur-ability	Wt. Reduction Concepts	Alloy Development		
Multi-material Systems	Joining	Corrosion	Body Structure Design	New Assembly Operations	NDE & Life monitoring
Glazings	Low-Cost Lightweight Matls.	Noise, Structure Models Simulations	Noise Reduction Techniques	UV and IR Blockers	
Metal-Matrix Composites	Feedstock Cost	Compositing Methods	Powder Handling	Compaction	Machining & Forming
Titanium	Low-Cost Extraction	Low-Cost Production	Forming & Machining	Low-Cost PM	Alloy Development

UNDER REVISION

Materials Technology Program Budget – Past & Present

- Lightweight Materials – this subprogram is focused on 1) Properties and Manufacturing, 2) Multi-material enabling, and 3) Modeling & Computational Materials Science
- Propulsion Materials – this subprogram is focused on 1) Engine Materials, Cast Al & Fe High Temperature Alloys, 2) Exhaust System Materials, Low Temperature Catalysts, and 3) ICME

Funding in millions	**FY 2016** Enacted	**FY 2017** Enacted
Materials Technology	$27.0	$28.1
Lightweight Materials	$21.6	$22.4
Propulsion Materials	$5.3	$5.7

Program Accomplishments: Multi-Material Joining

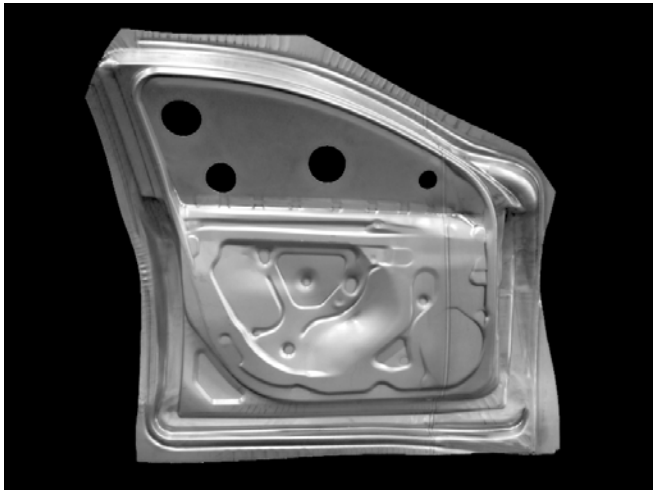
High Strength, Dissimilar Alloy Aluminum Tailor Welded Blanks

Pacific Northwest National Lab, Richland, WA

Other Participants: General Motors, TWB Company, Arconic, Inc.

Objective

Develop joining technology needed for high speed fabrication of high strength, dissimilar alloy Al-TWBs in linear and curvilinear geometries. Develop and validate predictive modeling tools for these welds. Introduce into the high volume automotive supply chain.



October 2015 – September 2017

Total project budget: $2,400K

DOE Cost Share: $1,200K

Innovations

- Developed process parameters for effective joining of work hardenable and precipitation strengthened alloys.
- Improved predictive modeling tools using high temperature flow stress information demonstrate more accurate fit than with stress-strain behavior alone.

Impacts

- Increase the optimized and combined use of Al alloys and thicknesses leading to **mass reduction** and improved **fuel efficiency**
- Achieve greater weight savings at lower cost penalty as compared to Al assemblies

Program Accomplishments: Metals

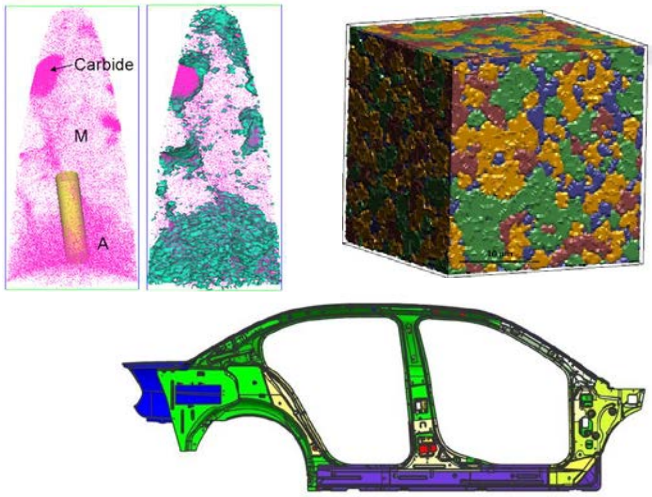
ICME Development of Advanced High Strength Steel for Lightweight Vehicles

USAMP, Southfield, MI

Other Participants: ArcelorMittal, AK Steel Corporation, Nucor Steel Corporation, U.S. Steel, Auto/Steel Partnership, LSTC, Pacific Northwest National Lab, Brown University, Clemson University, Colorado School of Mines, Ohio State University, University of Illinois

Accomplishment:

Developed and applied an integrated experimental/computational framework to produce two steels: >1200 MPa UTS, >30% elongation, >1500 MPa UTS, >25% elongation. The team used these steels to design an automotive structure weighing 29% less and has better crash performance and stiffness than the baseline at a cost of less than $3.18 per pound saved.



October 2011 – March 2017

Total project budget: $8,257K

DOE Cost Share: $6,000K

Innovations

- Leverage a team with broad expertise to build a validated computational framework that predicts steel properties as a function of chemistry and microstructure
- Achieve unprecedented combinations of strength and ductility in advanced high strength steels

Impacts

- Model framework developed as part of a commercial FEA package (LS-DYNA) to provide an essential tool to industry
- Outstanding properties reduce weight and manufacturing cost of safety critical structures

Program Accomplishments: Carbon Fiber Composites

Advanced Oxidation and Stabilization of PAN-based Carbon Fiber Precursor

Oak Ridge National Laboratory, Oak Ridge, TN

Other Participants: RMX Technologies, 4M Industrial Oxidation. C.A. Litzler Company

Objective

Developed a faster oxidation process to remove the bottleneck of carbon fiber conversion to further lower the cost of carbon fiber

October 2011 – September 2015
Total DOE budget: $6,000K

Innovations

- Developed a new plasma oxidation technology that cuts the oxidation processing time by a factor up to 3 times.
- Demonstrated scalability, robustness, and low variability of this process.
- Reduced unit energy consumption by 75% and lowering production costs by 20%.

Impacts

- Significantly reduced carbon fiber production line footprint.
- 4M Industrial Oxidation has commercialized this technology.

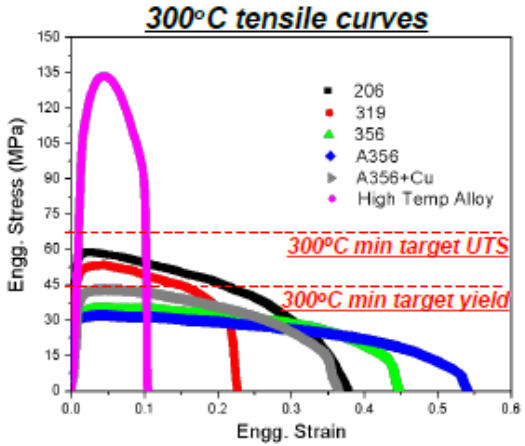
Program Accomplishments: Propulsion Materials

High Performance Cast Aluminum Alloys for Next Generation Passenger Vehicle Engines

Oak Ridge National Laboratory, Oak Ridge, TN

Other Participants: CRADA Partners: Fiat Chrysler Automobiles (FCA) and Nemak; Collaborators: Granta MI, ESI North America, Flow Science, MAGMA Foundry Technologies, and Minco.

Objective: To develop high-performance cast aluminum alloys characterized by improved castability, high temperature strength, and fatigue performance so that engine cylinder heads fabricated with the new alloy will have more than 25% improvement at 300°C compared to baseline properties at 250°C at a cost no more than 10% higher than heads manufactured by alloys 319 or 356. Also, to evaluate adequacy of existing ICME models and codes for the prediction of properties and development of alloys.



November 2012 – November 2017

Total Project Budget $5,500K

DOE Cost Share $3,500K

Innovations

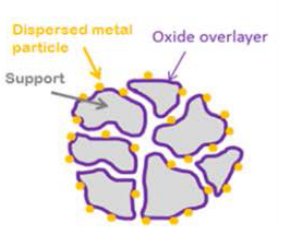
- New higher temperature alloys have been developed that meet all technical criteria for the funding opportunity.
- Tensile properties exceed 300°C targets by greater than a factor of 2. High temperature goals exceeded and alloys with stable microstructures up to 350°C have been developed.
- These alloys demonstrate outstanding hot tear resistance when cast as full scale components.

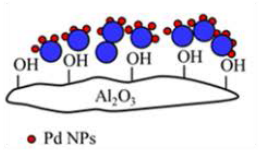
Impacts

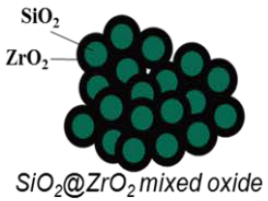
- Research team has cast a number of alloy compositions with the above these newly developed characteristics and filed a U.S. patent application for 350°C stable alloys.

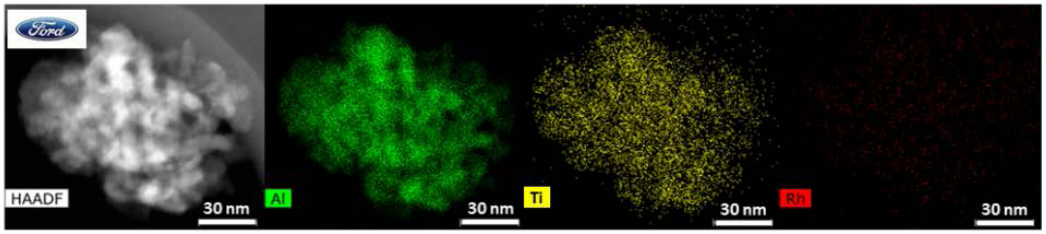
Program Accomplishments: Low Temperature Catalysts

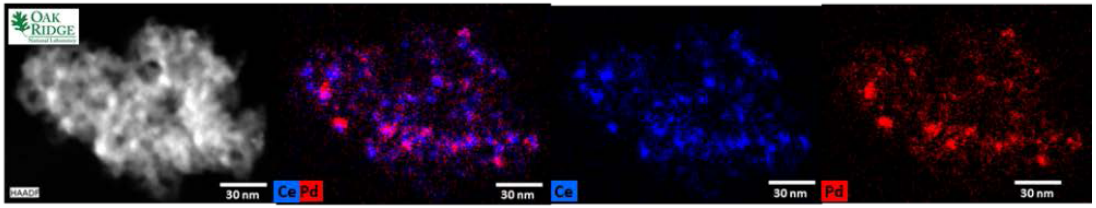
2013 FOA Award: Next Generation Three-Way Catalysts for Future, Highly Efficient Gasoline Engines

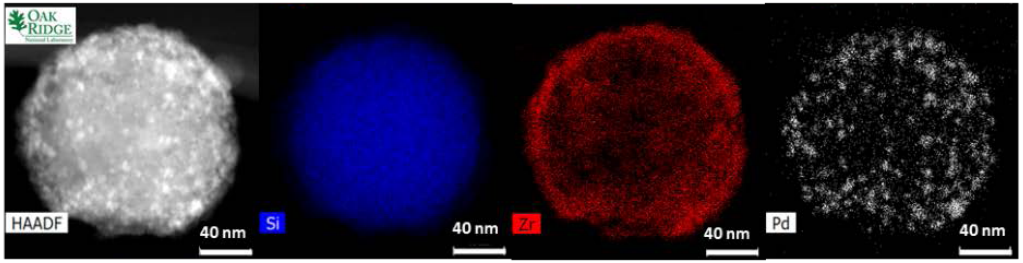


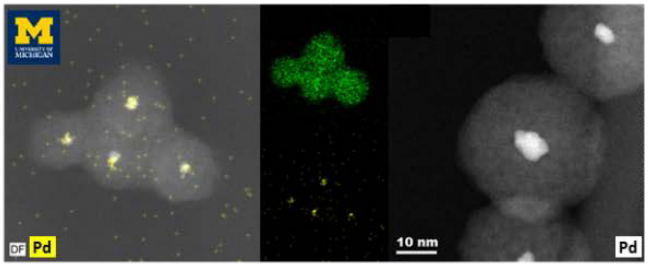












Micrographs and elemental maps recorded with FEI Talos F200X STEM provided by the Department of Energy, Office of Nuclear Energy, Fuel Cycle R&D Program and the Nuclear Science User Facilities.

USDrive 150C T90 goal

Progress 50% to Goal

Baseline T90 temperature for CO, HC, and NO

Materials Technology Program - Partnerships

Original Equipment Manufacturers

FCA FIAT CHRYSLER AUTOMOBILES
GM
Ford
HONDA
Cummins
USAMP UNITED STATES AUTOMOTIVE MATERIALS PARTNERSHIP LLC

Industry Partners

ARCONIC
INDUSTRIAL OXIDATION
DOW
INFINIUM
MAGNA COSMA INTERNATIONAL
TWB
PPG RAX TECHNOLOGIES
USS
U. S. Steel
tpi COMPOSITES
INTERMOLECULAR FAST FORWARD THINKING
XTALIC
JM Johnson Matthey

National Laboratories

OAK RIDGE National Laboratory
Pacific Northwest NATIONAL LABORATORY
BERKELEY LAB
Argonne NATIONAL LABORATORY
INL Idaho National Laboratory
LightMAT Lightweight Materials Consortium

Universities & Research Centers

ASU Arizona State University
CUICAR CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH
JOHNS HOPKINS WHITING SCHOOL of ENGINEERING
THE OHIO STATE UNIVERSITY
Composite Vehicle Research Center CVRC Michigan State University
UF UNIVERSITY of FLORIDA
UNIVERSITY OF MICHIGAN
NORTHWESTERN UNIVERSITY QUAECUMQUE SUNT VERA 1851
UNIVERSITY OF MARYLAND 18 56
UtahStateUniversity

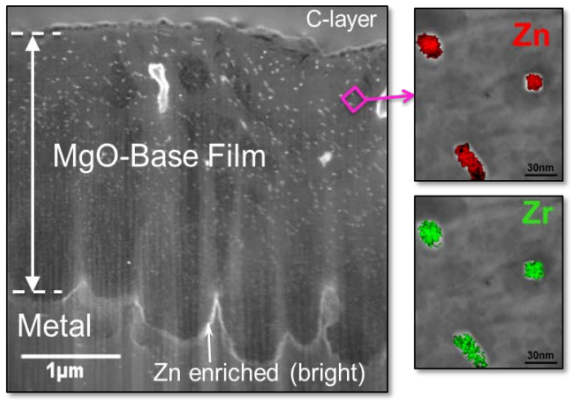
LightMAT: Lightweight Automotive Materials Consortium

LightMAT
Lightweight Materials Consortium

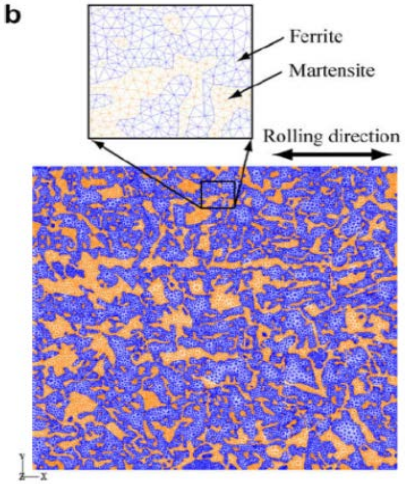
Ames Laboratory · Lawrence Livermore National Laboratory · Oak Ridge National Laboratory · Argonne National Laboratory · Los Alamos National Laboratory · Pacific Northwest National Laboratory · INL Idaho National Laboratory · NETL · Sandia National Laboratories · NREL

- **Connects the automotive industry with National Laboratory resources to facilitate lightweight materials research**
  - Low Cost Mg Sheet (USAMP)
  - Die Durability for Extruded High Strength Al (SAPA)
  - Mixed Metal Composite Brake Rotors (Arconic)
  - Carbon Fiber Reinforced Epoxy Coating on Steel (Arcelor Mittal)
  - Corrosion Mitigation of Mg (Magna)
- **Consortium of 10 National Laboratories with > 120 unique capabilities in materials characterization, computational tools, and manufacturing**

Characterization



Computational Tools



Processing / Manufacturing

www.LightMAT.org

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Conclusions

Upcoming Big Milestones

- Producing and testing ultra-lightweight doors (Vehma, TPI, Clemson)
- Target low-cost carbon fiber research (ORNL)
- Lower cost, high throughput multi-material joining technologies (PNNL, ORNL)
- Casting and machining cylinder heads from new lightweight powertrain alloys for testing in extreme environments (ORNL)

Conclusions (cont'd)

Technical Challenges and Opportunities

- Multi-material systems enablers and joining technologies
  - Innovative joining technologies of CF, Mg, Al, HSS
  - NDE tools for inspection & in-process monitoring
  - Predictive weld model tools (ICWE; machine learning; big data)
  - Corrosion prevention/coating materials
- Low-cost carbon fiber and composites
- Low-cost, high-volume manufacturing processes
- High-temperature alloys development
- Low-temperature combustion

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https://energy.gov/eere/vehicles/vehicle-technologies-office-lightweight-materials-cars-and-trucks